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Feasibility Study on Using Low Grade Silicon Carbide and Stone Sludge to Fabricate Eco Bricks

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Abstract

The aim of this study was to introduce 5% up to 40% of low grade silicon carbide (LGSC), with construction excavated soil before the soil being reused as raw material in Eco brickmaking. Furthermore, stone sludge was added to mix with LGSC to fabricate eco bricks. The results indicated that the use of 10% granite sludge, 30% LGSC and 5% brick waste clinkers could produce grade-2 eco bricks in sintering temperature 1,050℃, however 30% granite sludge was substituted to obtain the same grade eco bricks. Water absorption of eco bricks has increased during the addition ratio of LGSC increased. However, the compressive strength increased while water absorption decreased during the operation temperature increased from 1,020℃. to 1,050℃.

Keywords: silicon carbide, granite sludge, eco bricks, LGSC

1. Introduction

The increasing of environmental awareness has led to the rise of the solar energy industries. In order to maintain the lubrication of the cutting operations in the production of silicon chips in solar panels and cutting fluids. The mixture of cutting oils and silicon carbide powder, are added during the cutting process. To maintain the lubrication function of the cutting operations, the cutting fluid must be replaced regularly, thus generating large amounts of waste cutting fluid. The waste cutting fluid can become reused waste. Through physical separation methods, the waste cutting fluid can be separated from the solid waste. They are mainly consisting of silicon carbide, silicon, and a small amount of Diethylene glycol, also known as low grade silicon carbide (LGSC). The silicon carbide particles in the LGSC are relatively stable and do not undergo any changes or deterioration in quality during the cutting process; they account for 46.56% among of the LGSC [1]. Element silicon is the main impurity of the LGSC, together with other impurities such as iron, copper, and zinc [2]. To purify and extract the silicon carbide in LGSC, the particles are first filtered through centrifugation and then mixed with the cleaning fluid in hydro cyclone, using the ion-exchange resin method to remove the dissolved solids. However, this method requires several steps, chemicals and produces a large amount of waste water; it also requires the regular cleaning of the ion-exchange resin and other components and thus have a relatively high cost.

The main rocks used in the stone processing industry are granite and marble. During the cutting, trimming, grinding, polishing and wastewater treatment process, the stone waste slabs and slag has been produced. The stone wasteful plates and sludge hold similar compositions of the original stone, and the output quantity is large, however the final disposal of the sludge is burial or reuse. Whereas stone wasteful plates and sludge can be reused as cement raw materials, concrete raw materials, gravel raw materials, chemical raw materials and building materials. Due to the poor sales, the number of resource recycling products is limited. However, Lokeshwari and Jagadish had used granite fines waste in eco-friendly building blocks [3], and Munir *et al.* demostrated waste marble sludge to incorporate thermally efficient fired clay bricks [4].

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Eco bricks are extensively made by the sintering of industrial waste [5], thus it is encouraged to recycle and reuse the industrial waste. In the eco bricks certified by the Renewable Resources and Green Product Review [6], the added industrial wastes includes ceramic waste, inorganic sludge, construction waste, water purification sludge, and glass waste. Pundienė *et al.* represented the effect of different preparation methods of silicon carbide aggregate on the properties of refractory concrete with cenospheres [7]. However, the current handling methods of LGSC consist only incineration and heat treating, used as a composite deoxidizing agent or a heating agent in steelmaking processes. Therefore, the main aims of this research is to study the optimal addition of LGSC. Also, the stone wasteful plates/sludge is to construct the excavated soil sintering processes and to make eco bricks for utilizing the characteristics of the silicon carbide; and silicon has improved the quality of such bricks, in turn leading to widespread application of LGSC eco bricks in buildings. The concept of this study using LGSC and stone sludge to fabricate eco-friendly bricks was iluustrated in Fig. 1. The grade determination of the bricks complies with the specifications of ordinary bricks pursuant to Chinese National Standard CNS382 in Taiwan. In general buildings, Grade 3 bricks should have a water absorption lower than 15% and compressive strength higher than 150 kgf/cm^2; Grade 2 bricks should have a water absorption lower than 13% and compressive strength higher than 200 kgf/cm^2, and Grade 1 bricks should have a water absorption lower than 10% and compressive strength higher than 300 kgf/cm^2.

Fig. 1 The concept of this study using LGSC and stone sludge to fabricate eco-friendly bricks

2. Materials and Methods

Four phases of experiments were conducted in this study, two kinds of construction excavated soil were selected for the tests. In Phase I during the soil characteristics analysis, one of the soil was identified as clay loam (31.5% sand separate, 6.1% silt separate and 62.4% clay separate), the other was classified as silt loam (20% sand separate, 77% silt separate and 3% clay separate). The sources for LGSC were obtained from the solid waste extracted from the waste cutting fluid recycled from two solar wafer plants in Taiwan, and were abbreviated as T Plant and M Plant. Inductively coupled plasma optical emission spectrometry (ICP-OES, Thermo Scientific) was then conducted to analyze the metal composition of the LGSC, while the elemental analyzer (Elementar vario EL III) was conducted to analyze the element composition of the LGSC. In Phase II, the addition, proportion of the LGSC was then added to the two types of construction excavated soil in the proportions of 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%, respectively. After mixing and air drying, the soils with LGSC were then sintered in high temperature ovens to make brick embryos of 5 cm x 5 cm x 1 cm size, the grade of brick embryos was determined to examine the quality. In Phase III, a fixed 5% of waste clinkers from brick factory was added in the process, and the sintering temperature has been increased from 1,020℃ to 1,050℃ to reduce the porosity of the brick embryo samples [8] and increase the strength and grade quality of the bricks. In Phase IV of this study, the proportions of stone wasteful plates and sludge 10%, 20%, 30%, 40%, 50% were added to substitute construction excavated soil for brick making, the grades of brick embryos were then determined.

3. Results and Discussion

3.1. Analytical results of LGSC (Phase I)

The results of the metal composition analysis of two plant sources of LGSC are shown in Table 1, and the date of element composition analysis is listed in Table 2. The major composition of LGSC are silicon and iron, however the aluminum composition of LGSC of M Plant (3,560 mg/kg) is much higher than that from T Plant (122 mg/kg), which affects the brick quality in a sintering process due to the high reactivity of aluminum. In addition, the carbon composition of LGSC of M Plant (13.06%) is higher than that from T Plant (1.9%), the results indicate the portion silicon carbide (SiC) in M Plant is higher than that in T Plant. Because of the hardness and low thermal expansion coefficient of SiC, the compressive strength of bricks is increased.

Table 1 Metal analysis result of LGSC from two plant sources

Analytical items	T Plant (mg/kg)	M Plant (mg/kg)
Si	537,000	286,000
Fe	77,300	40,300
Ca	845	1,090
Mg	291	296
Na	1,310	1,130
K	487	1,030
Al	122	3,560
Mn	237	291
Cd	2.36	1.56
Cr	20.1	22.1
Cu	1,510	810
Ni	41	41
Pb	11.3	2.32
Zn	366	527

Table 2 Element analysis result of LGSC from two plant sources

Element items	T Plant (%)	M Plant (%)
C	1.9	13.06
N	0.02	0.14
H	0.05	1.69
O	0.53	5.75
S	0.25	0.7

3.2. Results by adding LGSC to construction excavated soil (Phase II)

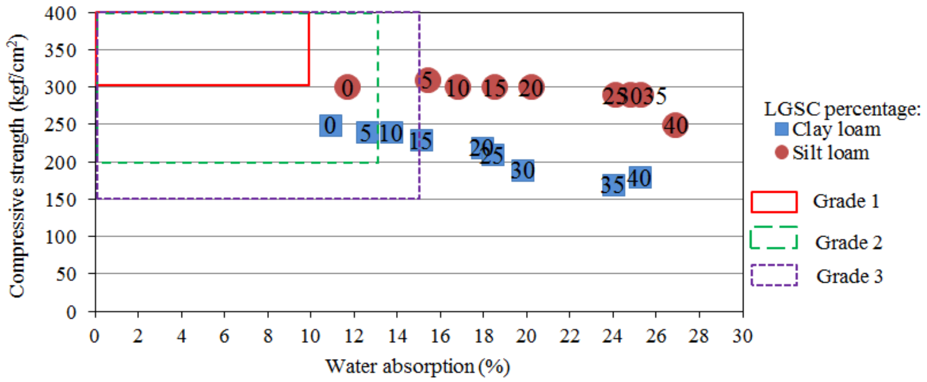

Fig. 2 Grade distribution chart of sintered bricks with different percentages of the LGSC from T Plant

The LGSC recycled from the two plants are added to the construction excavated soil at percentages of 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%. The grade distribution chart of the bricks made for the addition of LGSC from T Plant to the clay loam and silt loam is shown in Fig. 2 In the experiments, only LGSC were added at percentages of 0%, 5%, and 10% conform to the standards of Grade 3 bricks. The bricks without addition of LGSC have a water absorption of 10.9% and compressive strength of 250 kgf/cm^2 and are classified as Grade 2 bricks. Bricks added with 5% and 10% of LGSC have a water absorption of 12.6% and 13.7%, respectively, and both possess a compressive strength of 240 kgf/cm^2; thus, they are classified as Grade 3 bricks. Bricks added with 15% to 40% of LGSC have water absorption that exceeds the Grade 3 specifications but the compressive strengths remain within the scope of Grade 3 standards. The results show that when LGSC is added to clay loam, as the quantity addition increases, the water absorption increases, and the compressive strength decreases. Fig. 2 also shows the experiment results for the addition of LGSC recycled from T Plant to silt loam bricks. After the addition of LGSC, the bricks do not meet the standards of Grade 3 bricks. The results show that although the bricks have compressive strengths within the scope of the Grade 2 standards of 200 kgf/cm^2, the water absorption data are greater than the 15% standard required by Grade 3; therefore, the groups do not conform to the scope of the standards. When the LGSC recycled from T Plant is added to the two different construction excavated soils, the bricks show signs of poor water absorption performance, while the bricks sintered from silt loam have better compressive strength than those from clay loam.

The grade distribution chart of the bricks made for the addition of LGSC of M Plant to the construction excavated soil is shown in Fig. 3 When LGSC from M Plant is added to the bricks made from clay loam, the bricks show compressive strengths higher than 200 kgf/cm^2, which is within the scope of Class 2 bricks, but poorer water absorption performance. The water absorption of the bricks added with 0%, 5%, and 10% LGSC is 10%, 12.7%, and 11.8% respectively, which is within the scope of Grade 2 bricks. The water absorption of bricks added with 15%, 20%, and 30% LGSC is within the scope of Grade 3 bricks. Bricks with higher percentages of LGSC added do not fall within the scope of Grade 3 bricks. When the percentage of LGSC from M Plant added to clay loam is higher, the resulting bricks have poorer water absorption performance, but when added with 25% of LGSC, the bricks show a significant increase in compressive strength. When the LGSC from M Plant is added to the silt loam, after sintering, only the water absorption data of the four groups of bricks with 0%, 5%, 10%, and 15% LGSC added conform to the specifications of Grade 2 and Grade 3, while the others fail to meet the standards. However, the compressive strength of the bricks from all groups is higher than the Grade 1 standard of 300 kgf/cm^2, so bricks made from silt loam show a significant advantage in compressive strength than bricks made from clay loam.

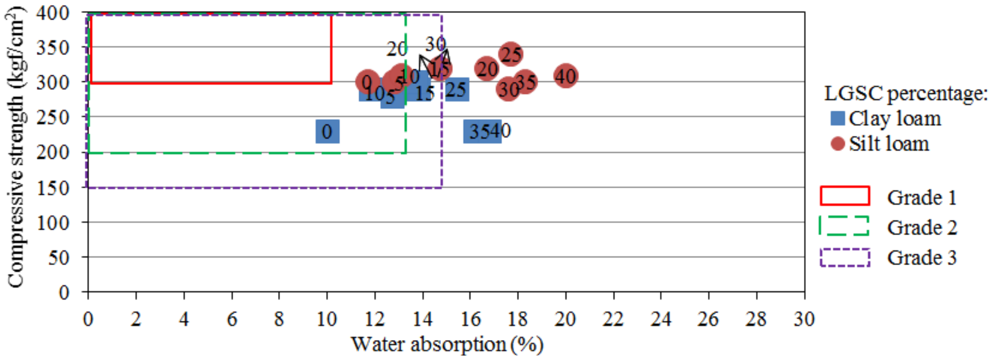

Fig. 3 Grade distribution chart of sintered bricks with different percentages of the LGSC from M Plant

3.3. Results by adding LGSC and brick waste clinker to construction excavated soil (*Phase III*)

The results of the addition of LGSC from T Plant and M Plant to clay loam and silt loam show that the addition of LGSC increases the water absorption of the brick embryo samples in all the experiments. Therefore, in the third phase experiment, a combination addition of 10%-25% of LGSC from T Plant or 25%-40% of LGSC from M Plant were added, together with 5% brick waste clinkers (BWC), to the construction excavated soil for brick sintering. As the BWC contain defects after sintering, the BWC is first crushed and pulverized into particles, after the particles with a diameter of 0.4 mm or less were added in the brick sintering process. During low temperature sintering, the BWC has low compactness, and the increase in pores results in an increased water absorption. However, at high temperature sintering, the waste clinkers have higher compactness, causing the water absorption to decrease. Therefore, the temperature of the brick sintering process in Phase II has increased from 1,020℃ to 1,050℃.

The grade distribution chart of the brick embryo samples made for the addition of LGSC from T Plant and 5% BWC to the construction excavated soil is shown in Fig. 4 The graph shows that the brick samples made from clay loam have a significant drop in water absorptions and an increase in compressive strength. The addition of BWC increases the grades of the bricks to the Class 2 standards. The brick embryo samples made from silt loam, also shown a sharp increase in grade levels, with the optimal condition being the addition of 15% LGSC and 5% BWC to the silt loam. The resulting brick is elevated to meet Class 1 standards.

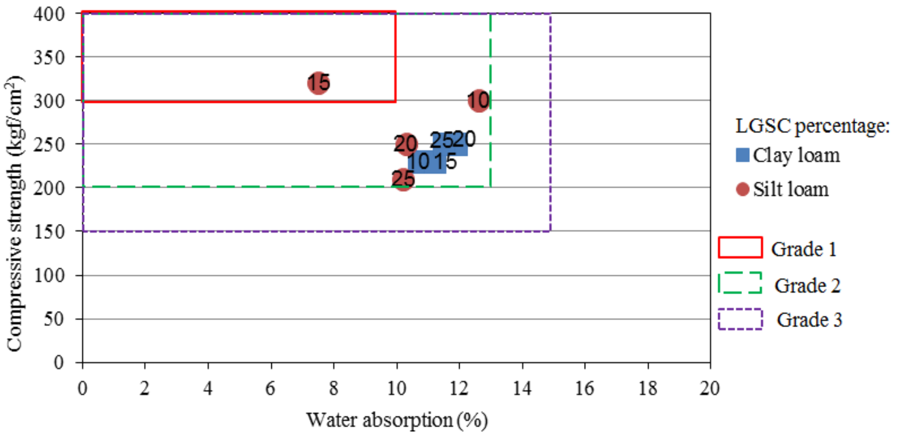

Fig. 4 Grade distribution chart of sintered bricks with different percentages of LGSC from T Plant and 5% of BWC added to the construction excavated soil

The grade distribution chart of the brick embryo samples made by the addition of LGSC from M Plant and 5% BWC to construction excavated soil is shown in Fig. 5. The graph shows that the bricks embryo made from clay loam exhibit a significant drop in water absorptions while the compressive strengths are not significantly affected. The bricks embryo made with the addition of the BWC belongs to Class 2. The bricks embryo made from silt loam shown a drastic drop in water absorption while the compressive strengths are not significantly affected. The bricks embryo made with the addition of 25%, 30%, and 35% LGSC belongs to Class 2, while the bricks embryo made with the addition of 40% LGSC meet the standards of Class 3 bricks. The results show that the addition of 5% BWC can reduce the water absorption of the bricks embryo made from the silt loam group. Although the increase in compressive strength was minor, the grade of the resulting bricks embryo has increased.

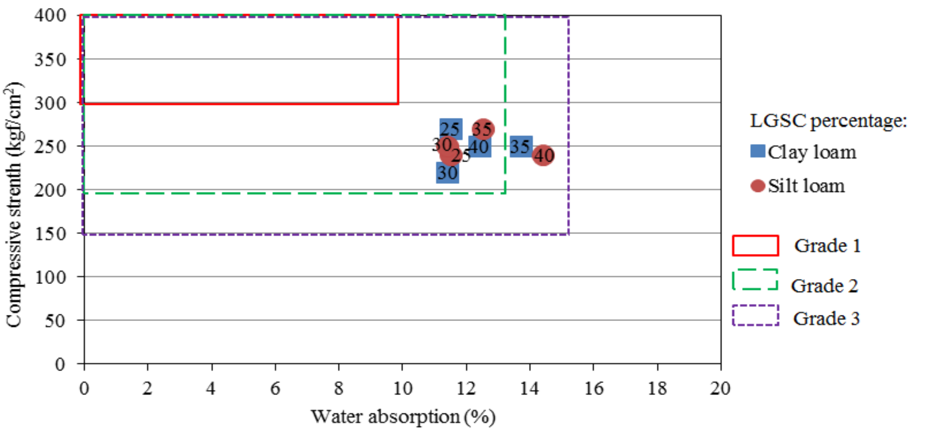

Fig. 5 Grade distribution chart of sintered bricks with different percentages of LGSC from M Plant and 5% of BWC added to construction excavated soil

3.4. Results by adding LGSC and stone sludge to construction excavated soil (*Phase IV*)

Granite is a common type of felsic intrusive igneous rock that is granular and phaneritic in texture, granite is an igneous rock with between 20% and 60% quartz by volume, and at least 35% of the total feldspar consisting of alkali feldspar. Granite is nearly always massive (lacking any internal structures), hard and tough. The average density of granite is between 2.65 and

2.75 g/cm^3, its compressive strength usually lies above 2,000 kgf/cm^2. Herein, granite sludge has been selected to fabricate eco bricks in this study. The composition ratio of 10%-30% LGSC from M Plant, 10%-50% granite sludge and the other portions (clay loam and 5% BWC) are mixed to fabricate eco bricks at sintering temperature 1,050℃. The water absorption and compressive strength of eco bricks are listed in Table 3. The Grade distribution chart of sintered bricks with 30% LGSC and various percentage of granite sludge without adding BWC and adding 5% BWC are shown in Fig. 6 and Fig. 7, respectively. The bricks do not meet the standards of Grade 3 bricks when the composition ratio of granite sludge is above 30%. The comparison of Fig. 6 and Fig. 7 indicate that the addition of 5% BWC is insignificant increase of brick grade when granite sludge is adopted.

Table 3 Water absorption and compressive strength by adding LGSC and granite sludge to fabricate bricks

Composition ratio (%)	Water absorption (%)	compressive strength (kgf/cm^2)
Granite sludge 10%+LGSC 10%+ Clay loam 80%	7.48	267.98
Granite sludge 10%+LGSC 10%+Clay loam 75%+BWC 5%	4.94	230.01
Granite sludge 10%+LGSC 20%+Clay loam 70%	7.02	240.96
Granite sludge 10%+LGSC 20%+Clay loam 65%+BWC 5%	7.13	239.04
Granite sludge 10%+LGSC 30%+Clay loam 60%	11.13	208.18
Granite sludge 10%+LGSC 30%+Clay loam 55%+BWC 5%	9.22	212.71
Granite sludge 20%+LGSC 10%+Clay loam 70%	7.53	200.80
Granite sludge 20%+LGSC 10%+Clay loam 65%+BWC 5%	10.14	199.60
Granite sludge 20%+LGSC 20%+Clay loam 60%	8.08	254.43
Granite sludge 20%+LGSC 20%+Clay loam 55%+BWC 5%	7.55	218.08
Granite sludge 20%+LGSC 30%+Clay loam 50%	8.93	213.55
Granite sludge 20%+LGSC 30%+Clay loam 45%+BWC 5%	7.23	214.39
Granite sludge 30%+LGSC 10%+Clay loam 60%	9.16	227.72
Granite sludge 30%+LGSC 10%+Clay loam 55%+BWC 5%	10.20	217.39
Granite sludge 30%+LGSC 20%+Clay loam 50%	7.14	215.69
Granite sludge 30%+LGSC 20%+Clay loam 45%+BWC 5%	12.45	213.97
Granite sludge 30%+LGSC 30%+Clay loam 40%	9.06	220.00
Granite sludge 30%+LGSC 30%+Clay loam 35%+BWC 5%	10.82	191.11
Granite sludge 40%+LGSC 10%+Clay loam 50%	15.82	232.96
Granite sludge 40%+LGSC 10%+Clay loam 45%+BWC 5%	13.75	257.93
Granite sludge 40%+LGSC 20%+Clay loam 40%	16.65	209.81
Granite sludge 40%+LGSC 20%+Clay loam 35%+BWC 5%	14.06	228.17
Granite sludge 40%+LGSC 30%+Clay loam 30%	17.06	191.86
Granite sludge 40%+LGSC 30%+Clay loam 25%+BWC 5%	17.03	182.26
Granite sludge 50%+LGSC 10%+Clay loam 40%	13.75	213.40
Granite sludge 50%+LGSC 10%+Clay loam 35%+BWC 5%	15.98	210.84
Granite sludge 50%+LGSC 20%+Clay loam 30%	15.93	196.45
Granite sludge 50%+LGSC 20%+Clay loam 25%+BWC 5%	15.60	196.84
Granite sludge 50%+LGSC 30%+Clay loam 20%	17.83	201.85
Granite sludge 50%+LGSC 30%+Clay loam 15%+BWC 5%	16.93	203.44

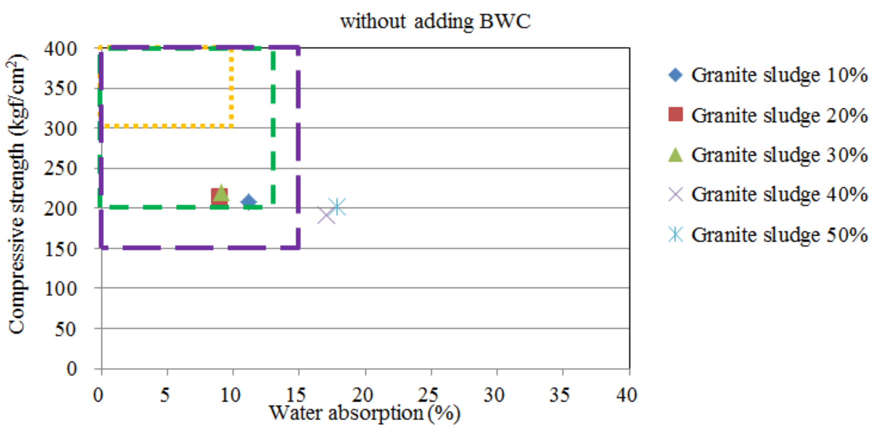

Fig. 6 The Grade distribution chart of sintered bricks with 30% LGSC and various percentage of granite sludge (without adding BWC)

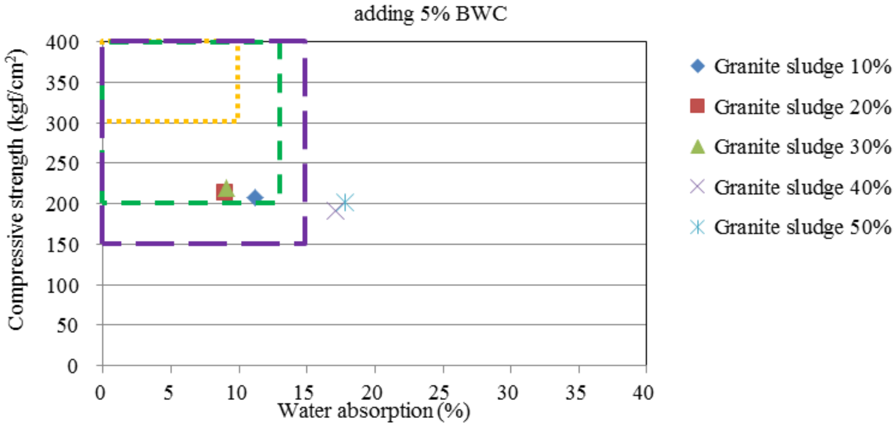

Fig. 7 The Grade distribution chart of sintered bricks with 30% LGSC and various percentage of granite sludge (adding 5% BWC)

4. Conclusions

This feasibility study demonstrates that the LGSC from the solar industry and granite sludge can be used to substitute clay in brick fabrication. When LGSC and granite sludge are introduced in bricks fabrication, the quantity of LGSC addition increases, the water absorption of brick increases, and the compressive strength decreases. However the bricks sintered from silt loam show a significant advantage in compressive strength than bricks made from clay loam. The addition of BWC increase the grades of the bricks to the Class 2 standards. The brick samples made from silt loam also show a sharp increase in grade levels. When granite sludge is adopted by brick making, the bricks do not meet the standards of Grade 3 bricks when the composition ratio of granite sludge is above 30%, the addition of 5% BWC is increased insignificantly of brick grade when granite sludge is adopted.

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Conflicts of Interest

The authors declare no conflict of interest.

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